The Institute of Physics

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CONTENTS

NOTICES TO MEMBERS
Page 297

OXFORD CONVENTION : DINNER IN CHRIST CHURCH
Page 298

PHYSICS AMONG THE SCIENCES
Sir Cyril Hinshelwood
Page 300

THE PLACE OF PHYSICS IN THE SCOTTISH LEAVING CERTIFICATE AND IN THE G.C.E.
D. McGill
Page 305

PHYSICAL SOCIETY MEETINGS
Page 309

REVIEWS OF BOOKS
Page 310

CORRESPONDENCE
Page 316

NEWS OF MEMBERS
Page 319

FORTHCOMING INSTITUTE MEETINGS
Page 321

THE INSTITUTE'S JOURNALS
Page 322

The Bulletin is published by The Institute of Physics for circulation to its members.

Notices to Members

The Oxford Convention

Although the number of members and guests attending the third Convention at Oxford in July was less than the attendance at Bournemouth, the decrease was mainly accounted for by the much smaller number who came for only part of the Convention proceedings. The general opinion appears to be that the Convention was highly successful and thoroughly enjoyed by all who attended. Among the highlights was the dinner in the Hall of Christ Church, with speeches by the President, Lord Chandos, Sir John Cockcroft, and Professor W. E. Lamb, jun. Some photographs taken at the dinner and the reception by the President and Mrs. Humphreys which preceded it, are reproduced on pages 298, 299. The address by Sir Cyril Hinshelwood, President of the Royal Society, given in the Sheldonian Theatre, is published in this issue of the *Bulletin*. A report of the discussion on science and the humanities, introduced by Mr. Alan Bullock in a brilliant and stimulating talk, will appear in a later issue.

Physics in Industry Series—new volume

The new volume in the Physics in Industry series—*Pressure Measurement in Vacuum Systems* by J. H. Leck—will be published about the middle of October. The retail price is 30s.; members of the Institute (Fellows, Associates, Graduates, Subscribers and Students) may obtain copies for their **personal** use at 25s. each. An order form is enclosed with this issue of the *Bulletin*.

Oxford Convention : Dinner at Christ Church, July 10, 1957

The President, Lord Chandos and Mrs. Humphreys.

The President and Mrs. Humphreys with Sir John and Lady Cockcroft.

The President and Mrs Humphreys with Dr. and Mrs. T. E. Allibone.

Dr. J. M. A. Lenihan, Mrs. Lenihan, Mr. A. E. De Barr, Mrs. De Barr.

Dr. J. Topping, Mrs. Topping, Dr. G. W. Scott-Blair, Mrs. Scott-Blair.

Mrs. W. E. Lamb, Sir John Cockcroft, Mrs. Humphreys, Lt. Col. D. V. Hill.

Mrs. J. Taylor, Professor F. A. Vick, Mrs. K. A. G. Mendelssohn, Mr. T. C. Keeley

Mr. E. R. Davies, Mrs. Davies, Mrs. Menzies, Dr. A. C. Menzies.

Mrs. M. H. H. Bunton, Miss T. J. Dillon, Dr. E. M. Warren, Mr. J. Bunton, Mr. G. W. Warren.

Dr. J. S. Forrest, Mrs. Forrest, Mr. A. J. Davies, Dr. J. V. Dunworth.

Physics among the Sciences *

By Sir CYRIL HINSHELWOOD, F.R.S.

(*Dr. Lee's Professor of Chemistry, University of Oxford; President of the Royal Society*)

A MAJOR necessity in Britain to-day is that men of science should vindicate the right of their subject to recognition, in the general understanding, among the humane studies. The title humane, as far as I can gather, was probably first applied to those branches of learning which threw off the irksome control of scholasticism and asserted the freedom of human enquiry against a dogmatism allegedly based on divine authority. Not unnaturally the first scholars called humanists were much attracted to the storehouse of learning offered by the ancient pagan classics, but to the study of classics has since been added that of history, philosophy and indeed practically everything save natural science.

The original antithesis between human and theological has gradually been transformed into one between the study of man and that of the universe in which he finds himself. The shift of meaning would have done little harm were it not that the word humane has overtones of civilization, culture and kindliness, qualities which by implication are fostered by the study of the arts and neglected if not actually blighted by that of science. Many absurdities spring from this dichotomy of knowledge. The views of Kant on space and time in the current system of values count as humane, those of Einstein do not. The power of words to move and to clarify is great and their power to deceive is even greater and stranger.

The proper study of mankind may be man, but it is indeed an extraordinary belief that man can be understood without reference to his evolution, his physical constitution, his environment, and most of all without reference to his tremendous adventure of searching into the deep mysteries which surround him, mysteries the solution of which we could even, by a surely not impious fancy, conceive to be one among others of the purposes of his terrestrial sojourn.

Knowledge should be a unity. As men of science we are so beset with the difficulties and complexities, and indeed with the beauty and fascination, of our own parts of it, that we find difficulty in keeping an eye on the great world as a whole. But we must be on our guard against that parochialism, which might give a new kind of justification to the denial of humane status.

Do you remember the story about the yokel who was asked by a motorist the way to Leeds. He replied scornfully, "*I* shouldn't *start* from here." The answer illustrates a certain lack of reference to any general co-ordinate system. Correspondingly it is painfully easy in science to find oneself in the position of the yokel in one's own subject and of the motorist in someone else's. But we have to try to do better.

I was proposing therefore this evening, since you have come together for the discussion of physics, to invite you to reflect a little on a few aspects of the relation of physics to other branches of science. And, in this connection, since we protest at the exclusion of science from the realm of humane studies, we must show reciprocity by admitting even philosophy as a valuable ally of science itself.

The consideration given to these vast questions must of course be cursory, and if my choice of theme is partly to uphold a general principle, the treatment of the theme will, I am afraid, rest on a quite arbitrary selection of a few among an almost infinite variety of topics.

Physics is a great and magnificent study. Theology was once enthroned by some as the Queen of the sciences. Theologians even laid

* An address given to the Institute Convention at Oxford, July 11, 1957.

down the law on what we should now call scientific matters, especially on cosmology and on evolution. Newton himself seems to have devoted as much attention to theology as to science, and the clear recognition of two nearly autonomous co-existing worlds of thought is on the whole a modern conception. In the scientific world of to-day physics seems in some ways to have been put forward as claimant for the crown, on the ground that it deals with the ultimate laws determining the structure of the universe, the forms of matter and energy, and their interactions, and perhaps also on the ground that the so-called ultimate particles and problems connected with the atomic nucleus present some of the deepest and most inscrutable mysteries.

Yet here biology is a powerful rival : the mysteries of the living cell, and the marvellous processes of autosynthesis have a grandeur quite comparable with that of the geometry of space, the quantum or the meson. Biology is no longer descriptive, and the jovial remark which Lord Rutherford, I am told, once made to Sir Gowland Hopkins, " I say, Hoppy, it must be darned easy to be a biologist " has now an old fashioned ring. Perhaps one might say that physics has taken over biology. But when the invader is assimilated by the invaded, who has taken over whom ? It can also be said by way of debate that all the rational parts of chemistry are physics : but with equal justice the reply can be made that in some fields of physics it is only chemistry which covers some very bare bones with flesh.

If physics claimed sovereignty over other realms, claims over it of a very obvious nature might of course be made by mathematics, without which after all it would be in an even sorrier pass than chemistry would without physics, or biology without chemistry and physics together. And so there is really only one conclusion : that these claims and counterclaims are not legitimate material for more than mere badinage. The claimants are like the philosophers that the Roman emperor called to dispute before him in order, not that he might be enlightened, but that he might be diverted by their dissensions. The truth is that nature is an indissoluble unity, all the parts working harmoniously one into the other. It is the mode of this interlocking which provides a study infinitely more rewarding and fascinating than any dispute about precedence or hierarchical ordering.

Perhaps we might spend a little time considering the relations of physics to some of its neighbours in turn, and I will begin with chemistry. Chemistry only begins after atoms have been formed from nuclei and electrons, and indeed, in the true sense, after atoms have united to form molecules. The obscurer secrets of the nucleus are hardly the concern of the chemist, who only needs its mass, charge and spin. But the laws which govern the marshalling of electrons around nuclei, and the circumstances which determine the union of atoms to molecules are in a way the joint responsibility of chemists and physicists. In the hotter stellar regions the physicist and his close relation the astronomer are left to their own devices, but for habitable worlds chemistry comes into its own at an early stage.

The laws governing the formation of atoms and molecules are peculiar indeed. As we know, the groupings of electrons, whether in atoms or in molecules, are subject to the quantum laws which prescribe the possible energy states of systems. These states are defined in the first instance by the possible solutions of a differential equation, the famous wave equation. It was arrived at by a series of inspired guesses, but it is not logically derivable, and the fairly complicated rules for operating it, although they can be made to look plausible, are not clearly predictable from one single, simple, fundamental principle. Nor is the equation itself of a particularly simple or elegant form.

Thus the common basis of large parts of physics and chemistry retains a considerable element of what is not only empirical but a little complicated and even inelegant. The Schrödinger equation may perhaps be likened to Atlas bearing the world. There are some suggestive glimpses of the tortoise on whose back Atlas stands, but the lake on which this beast in its turn swims is rather misty. The success of the deductions from the

equation is amazing. But if we want to understand the world in the old fashioned sense of understanding, there is still a lot to be discovered. Some philosophers in this University tend, of course, to say that the quest for this kind of understanding leads only to the asking of meaningless questions. They may be right, but I do not believe them.

To return to the joint preoccupation of chemists and physicists with atoms and molecules, to settle this matter the quantum laws are not enough. These rules by themselves would not predict the beautiful system of the chemical elements and the wonderful periodicity of their properties : nor would they unambiguously account for the formation of chemical bonds between atoms. For these purposes we must invoke the Pauli principle, which is the very cornerstone of chemistry, and therefore of habitable worlds, and of life. This principle, or more formally that of the antisymmetry of electron wave functions, tells us in effect that all the electrons in a system must be distinguishable one from the other in at least one of their quantum prescriptions. Just as the Pauli principle is the mainstay of chemistry, so in its turn the confirmations provided by the chemical elements and their compounds form the best support of what must be regarded as one of the most fundamental principles of Nature.

It is more luminous and aesthetically satisfying than the wave equation (or equivalent mathematical system). Yet it, too, has a baffling quality about it, and a quality of a quite special character. The fact that the possible existence of two individual entities in a system is correlated with the possibility of their distinguishability one from the other by separate inspection seems to bring us more directly than almost any other phenomenon to the boundary where philosophy and the physical sciences meet. We seem to stand before a gate behind which lies the solution to a great mystery. But the key to open it is missing. Are chemistry and physics in the last resort both dependent upon some deeper theory of knowledge ?

In a world of matter and motion a vast array of phenomena are dominated by the principles of statistical mechanics. These might seem to be rather severely the province of the physicist. Yet their most spectacular success is in providing the key to the whole problem of chemical equilibrium, and so the definition of the proportions in which all the atoms and molecules in the world settle down and distribute themselves between their various possible configurations. In a sense, therefore, they are the very stuff of chemistry.

The fundamental principle, stated with a little over simplification for brevity, is as follows : Different energy states are treated like so many boxes, and the allocation of atoms and molecules to the various boxes occurs randomly in accordance with the laws of chance. The size and nature of the boxes follow from the quantum laws and are quite elaborate functions of the properties of the various atoms and molecules, but it is the simple statistical principle that in large measure governs the bewildering tangle which chemical substances present.

Here again the basic statistical principle itself is one which, elegant and simple as it is, is thought-provoking and elusive. The meaning of states and their ranges leads us again to the gates of philosophy.

The basic laws of physics, we may say, are empirical and we are content that they should be so. Yet there are many kinds of empirical knowledge with which we are not content. Nobody would prefer Kepler's laws to that of Newton for the description of the solar system. Newton's, we may say, is simpler, more elegant and more natural. But what constitutes simplicity, elegance and naturalness ? Some might claim that economy of effort is the sole criterion by which the laws must be judged : and yet, economy of what effort ? In the last analysis our recognition of what is a fundamental and satisfactory law seems to rest upon something outside physics.

There are many roads from physics into biology. I can indicate only one or two. One lies through chemistry. The quantum laws and the Pauli principle govern chemical union, and, as it appears, in a way which admits the existence of enormous macromolecules. These are the material basis of

life. The parts of living systems replicate themselves. One basis of this phenomenon is the potential energy principle which favours the building up of regular structures : another is the principle of entropy compensation which allows the formation of substances with high free energy to be financed energetically at the expense of degradations elsewhere. Yet another factor is a system of equations showing that many chemical syntheses can be co-ordinated in a way which leads to the harmonious reproduction of all the parts of a cell. Aggregations of cells into tissues and individuals follow analogous but more complex principles.

So far all this is very much an affair of physics and chemistry : and it is from this direction that a full solution—in one sense of the word solution—of the problem will probably come. The physico-chemical principles provide means of automatic adjustments and adaptations which in some examples give explanations for, and in others suggest rough models of what occurs.

All this is at the lower end of the scale of life. At the higher end of the scale neurophysiology is depicting the operation of the brain in a way that in some respects is highly reminiscent of an electronic computer. The human brain which conceived the machine, now, like the poet who in his wanderings found himself confronted by his own image, sees in what it has created the reflection of itself. Almost infinitely numerous interlocking circuits, providing patterns of activity, more easily re-excited when once traversed, provide material models of thought, association and memory. The electrical nerve processes themselves are being successfully described in terms of ionic movements, and in this whole field physics might at first sight be thought supreme.

Electronic machines are even said to think, but this assertion is an exuberant claim which will not stand careful examination. The operation of the brain in solving problems certainly recalls, and is indeed probably justly compared with that of the electronic machine working away until it has produced the required table of logarithms or list of squares. What must be remembered, however, is that the computer prints out its answer only when conditions prescribed in its so-called programme are duly fulfilled. The " programming " is the most skilled and difficult of all the arts involved in the use of computers, and can only be done by a human being, never by another machine (unless that machine has itself been programmed, and so on in an infinite regress).

The question is not one of mere complexity. The brain, it is true, has a number of cells transcending by many orders of magnitude the number of valves which anyone has even contemplated building into a machine, and the number of comparison patterns which it may store is correspondingly larger. But no matter how much any machine is elaborated, there is no dispensing with the operation of specifying the programme. In the working of the brain this specification involves elements outside the frontiers of anything that can reasonably be called physics. The machine is instructed that a given stage of its work is completed, when say the digits in a certain set become zero. The operations of the brain, however, often conform to certain needs of the aesthetic or ethical senses or the conscious emotions.

These belong not to physics but partly to philosophy and partly to biology. And by biology I mean here the parts of biology which are not translatable into the terms of physics (or chemistry). Speaking as one chiefly occupied with physical chemistry I think it is well to remind ourselves that such parts do exist. Whether the realms of psychology opened by Freud, or the almost incredible manifestations of the instincts in animals and insects will ever be fully treated without reference to principles which remain inalienably biological is at least an open question. Whether, too, automatic processes with the superposition of random variations and natural selection will ultimately give a completely satisfying account of the course of evolution is also by no means absolutely certain.

I shall pass over such phenomena as extrasensory perception, telepathy and psychic manifestations as too incompletely documented, and too inadequately analysed

statistically to be admissible as evidence at the present time.

I must confess that I am occasionally a little surprised by the insensitiveness of some exponents of physical science to the non-physical aspects of familiar problems. Not long ago I read a discussion of cosmological questions which gave good and sound reasons for believing that the number of inhabitable planets in the stellar universe might be enormously greater than was supposed in the days before the expansion of the cosmos was discovered. The writer went on to say that the emergence of life was an almost inevitable consequence of the existence of such conditions, and what he described as a " neurotic activity " of the living matter was then represented as something following quite naturally. Man was thus displaced from any central position in the universe, and it was suggested that the new picture might considerably change the status of religious beliefs.

I am very far from proposing to discuss religious questions, but there does seem here to be a complete *non sequitur*, with which it is a great pity to round off a subtle and fascinating astrophysical argument. What any man may believe about the ultimate purpose of existence can be little affected by his status in the world of space-time. Indeed I could not help reflecting with a tinge of amusement that had the author of the book of Job known of the probable insignificance of the Earth itself among all the planets of the Universe he would in his famous 38th chapter have added a verse or two even more majestically putting man in his place.

Physics and philosophy touch at many points, and each needs to beware of illegitimate incursions into the territory of the other, though in some ways the most interesting aspect of their contiguity is a neutral zone in which by common effort they may ultimately solve problems at present far from clear to either.

Consider the phenomenon of vision. Physics describes the propagation of the light from the object to the retinal image. A kind of physiology which is itself almost physics describes the nerve impulses and the brain processes. Then the act of seeing occurs. Just as a philosopher not sufficiently concerned with physics can easily go astray in his analysis of the events as a whole, so the physicist falls into error if he makes a facile identification of the brain process with the experience of seeing. People sometimes assert that the two are idential. The contrary may be realized by imagining a man who has been born blind and has acquired a good knowledge of mathematics. There will be no difficulty in teaching him about light waves, and their differing frequencies, about propagation of waves or photons, about nerve processes depending upon ionic displacements, and about patterns of cortical activity. But how do we express in equations the form of the red rose and the different sensations of the red of the petals and the green of the leaves. A specification of frequencies is useless in this respect : there is no possible means of stating in physical terms the quality of experience which he misses and which the normally endowed man has.

Are we then to say that what we call redness and greenness, apart from being synonyms of certain wave numbers or intensities of stimulus, are meaningless ? If we say yes to this question then I think we are suffering from a form of mental blindness ourselves.

Somehow, one feels, there must be a way of formulating our apparently dual apprehension of the world—by personal experience and by the use of our scientific intelligence—so that this disturbing discontinuity,the existence of which is referred to when we speak of the mind-matter problem, no longer exists. But what that way is, I cannot tell you.

There are other ways in which the philosophical frontiers of physics need more careful definition. The theory of relativity, according to which observers in motion relative to one another have their separate measures of time, has even been represented as a doctrine of a purely subjective world. It is, of course, nothing of the sort. In the world of space-time the measurements are perfectly objective, and there are, of course, quite elementary procedures for converting the data of one observer accurately into those

of another. All that has gone is any naïve faith in our ability by simple reflection, contemplation and the use of a faculty vaguely known as common sense to know the physical nature of space and time.

A related matter is raised by the discovery of the expanding stellar universe. Various systems of equations suggest an origin to the time scale, when the present recession began and when the material of the known universe was very highly concentrated indeed. This is sometimes referred to as the moment of creation, with presumably an implication that before it time did not exist. This, again, is an unfortunate mode of description. The mental difficulties of conceiving a beginning to time, and, as it were a time before time was, are so formidable that they have never been met by anyone. The time origin of cosmological theories represents something pretty exciting in the history of the physical universe but I take leave to doubt whether it has philosophical significance at all.

Even more nonsensical, upon calm reflexion, appears the alleged connexion between the uncertainty principle and free will. According to the principle certain dynamical quantities are not simultaneously determinable with precision (though each would be separately if knowledge of the other became still more inexact). The statistical result is, however, quite determinate on the macroscopic scale. A belief in free will on the other hand means that macroscopic events in human affairs are susceptible of continuous direction with not even statistical certainty. The two conceptions are quite different.

In passing it may be said that the attempts of some modern theologians to justify their beliefs on the basis of physics are equally inopportune. Science and traditional religion may well fit into a co-ordinate system which possesses more dimensions than either of the existing systems at the moment do separately, and that is all that can really be said.

It would be a great pity if physics were to impair the strength of a magnificent position in the scheme of things by any rough aggression beyond its bounds. But without invading further the province of philosophy, physics itself stands on the threshold of a wonderful enough revelation.

The situation in respect of the so-called ultimate particles is highly mysterious, and the resolution of the mystery when it comes cannot fail to be spectacular. These entities are not really particles and in view of their number and variety can hardly be called ultimate. At the moment we seem to be passing through the darkest hour before dawn. When that dawn comes something very wonderful will be revealed.

But what is the final synthesis ? The system which we construct must inescapably contain elements of personal choice : it is objective in that we cannot include what is not present in Nature, but it is subjective in so far as we alone judge in terms of what kinds of quantities and with what sorts of relations we think it worth while to describe the world.

We formulate concomitances which grow familiar rather than comprehensible. The electronic specification of atomic states changes : light quanta traverse space. The law connecting the two phenomena is well-known but the question " What happens " remains unanswered, or is dismissed as the kind of question that is not asked. But is the renunciation final ?

There are still some deeply obscure regions. Is it too much to guess that in a few centuries time our whole present way of thinking about things may seem as blindfold as that of the alchemists, astrologers or primitive magicians seems to us to-day.

Meantime we can leave these idle thoughts and return to our laboratories, where we are doubtless better employed than in thinking them.

The place of Physics in the Scottish Leaving Certificate and in the G.C.E.*

By D. McGILL, M.Sc., A.Inst.P.

(*Glasgow Academy*)

TEACHING physics north and south of the border, teaching physics in schools and in universities has led me to form definite conclusions about the merits of the H.L.C. compared with the G.C.E. as a first step in the training of physicists.

1.—Having taught in outstanding schools on both sides of the border, I am quite sure that the traditional broad Scots course studied to H.L.C. standard is a better end in itself and is in some ways a better preparation for more advanced and specialized studies than is the English school certificate course.

The standard of attainment required for the Scots H.L.C. is higher than for the English "O" levels in most of the principal subjects. The difference in standard varies with subject and method of assessment, but on the average amounts to about one year's work at fifth form level—an extremely significant difference, particularly on the arts side. The extra bite in quality given to the work (at best) fully justifies the proud claim of breadth with depth.

There are many people, myself included, who would rate this continuation of non-specialized work to the H.L.C. standard as being of first educational importance, and would contrast it favourably with the earlier and often premature specialization occurring in some English schools. I meet much distressing evidence, however, of methods of teaching for the Scots H.L.C. which must detract from its value at best. Where the Scots course has degenerated in this way into a mere instilling of knowledge it is more harmful than the English course just because it is longer.

Misunderstanding by English employers arises because of the anomalous position of science in the Scots H.L.C. course; the separate sciences, physics, chemistry, etc., count as half subjects only in the H.L.C. examination.

This examination is a very good attainment test but in the writer's experience a less successful selective device. As an attainment test it compares favourably with the English "O" level examinations in physics and chemistry; but these examinations in England do not determine the overall character of physics teaching in the schools to anything like the same extent as does the Scots H.L.C., because of the larger part played by sixth form work in England. The strength of the H.L.C. course in Scotland for the young scientist lies in its relatively high standards in mathematics and the arts subjects; the weakness lies in making an attainment test the aim and end of school science teaching.

To pass H.L.C. science a candidate must know his definitions, know how to describe and explain a fair number of experiments, know also what steps are necessary to ensure reasonable accuracy. He must also be able to reproduce standard book work such as derivations of important equations. The standard required in these ways is high and in total constitutes a very positive attainment. All of this work, however, can be learned by rote and much of it is in fact directly memorized. None of this demands understanding of physical principles and power to apply such principles to new situations, these vital factors being the essence of a

* Based on a lecture given at the Scottish Conference on Training in Physics held in Glasgow by the Institute's Scottish Branch and Education Group, April 12-13, 1957

selective test. True, that almost every question includes a numerical or algebraic problem and that these may be searching and selective in character (although more often they are of a routine nature, capable of being answered without real comprehension by a well-drilled candidate). Whether the problem be searching or not, however, it never carries a dominant proportion of the total marks. Thus, valuable as the H.L.C. science pass is to the community as evidence of attainment, it simply is not in itself adequate evidence of fitness to proceed to advanced studies, and without a further objective school science studies so determined are seriously handicapped in emphasizing sound values in the training and education of young scientists. (No one who has attended Science Masters Association meetings in Scotland can fail to be aware of the fine work done by many Scots science masters ; but this is despite, not because of, the nature of the H.L.C. examination.)

There is no reason of course why a first external examination should be selective in character, but this can only be tolerated at a national level provided that this is followed by a selective examination at a later stage. In Scotland this later selective examination is relegated to the university and there is great merit in this where adequate science teaching in schools cannot be provided. I would most strongly maintain, however, that an alternative road to advanced studies through sixth form work is essential in a sufficient number of schools to give adequate leavening and variety to the whole system.

2.—Consider first the relative merits of sixth form work and of the university first year.

Having been primarily responsible for the first year lectures, tutorials, and laboratory work in the physics department of a major English university, and having been head of science side in a major English grammar school, I am quite certain that at its best the grammar school sixth form is a better preparation for honours degree work than is the first year in a university physics department (by first year here and in what follows I mean first year Scots pattern, often called the intermediate year English pattern).

There are various rather obvious reasons why this should be so :

Staff to student ratios are much smaller in schools than in university first year classes.

School staffs are primarily interested in their pupils, university staffs in their subject. School staffs are appointed for their teaching ability, university staffs for their research ability.

Direct teaching at first, progressing to tutorial guidance later, is commonly more effective at this stage than is the lecture method. Indeed the latter is nowadays largely outmoded, discussion based on previously studied texts often being more effective. For a first rate scientist or science master to spend a precious hour presenting in lecture form material already available in excellent texts is often much less valuable than spending this time with students who have already studied the text, adding significance and clarity to thinking already active because of preliminary reading and more perceptive because of this.

With a minimum of two years' uninterrupted work, external examinations *can* be relegated to the background and spoon feeding give way to a more critical and more fully substantiated development (opportunities for this in England are richer where " O " level examinations are omitted for specialist subjects. I have had experience of this " direct road to the sixth form " and value it immensely). Red herrings must be pursued. Creative, imaginative study is killed when teaching is too ordered or too tightly specified by the time table or over detailed, over long examination syllabuses.

The member of the live sixth form learns much from his fellows in class discussion and in the science society, the lone student at the university much less from the more limited discussions characteristic of students attending *first* year lectures.

The good science sixth reacts richly upon the whole life of the lower school and this in turn ultimately enriches sixth form science. The future university student has much of value to learn from this.

Sixth form science is precious to the true science master, not only because of its

scientific interest, although this matters greatly, but also for the enormous gain in liberalizing science teaching afforded by the increased time and continuity effected with a given group of boys. Similar considerations apply, I think, but with diminished force to university first year work.

These general arguments for the science sixth rather than the university first year apply to both sides of the border.

3.—Having taught in a leading Scots Academy from which many boys pass each year to Scots universities and central institutions, both directly after H.L.C. and again after one year of sixth form work, and knowing something of the difficulties that beset the first year at the Scots university, I have no doubt that I could do more for the same boys in the sixth form than I could if they were members of my first year university class, total hours of work being comparable.

In Scotland, however, particular factors operate against the best interests of sixth form science. Foremost of these is the increasing tendency to use the sixth form as the final stage of the H.L.C. course. There may be merit in taking longer over the H.L.C. course but sixth form work must remain separate and additional to this. A sixth form year largely devoted to H.L.C. repeats is tragically wasted. Much the same is true where the sixth form work is concentrated on bursary examinations when these examinations merely perpetuate the deficiencies of the H.L.C. These papers surely should be selective in character and wholly discouraging to spoon feeding. Some of the bursary papers are of this type, delightfully so ; others, unfortunately, quite the reverse. A final difficulty arises by the provision of advanced papers in mathematics while physics and chemistry remain at half H.L.C. level. No physicist would cavil at the acquisition of useful mathematics but this unbalance between requirements in mathematics and physical science makes it difficult to secure balanced effort in the Scots sixth form.

While I do not think that the general purpose of the H.L.C. course would be furthered by introducing separate physics and chemistry papers at full H.L.C. level, believing the more general physics plus chemistry to be a more equitable match to general requirements at this stage, full papers in science subjects, broadly based but selective in character, assisted by comparable papers in mathematics, and all set four terms after H.L.C. would do much to give balanced drive to sixth form science. Such a provision might well give direct access to the university second year (as I believe St. Andrews University now proposes).

I would like to stress that in advocating full papers in science for Scots sixth forms, I am not advocating wholesale adoption of the English sixth form pattern. Education in depth we must have, but not over-specialization at school. Three years in the sixth form sees young manhood still shackled to an environment that is often fundamentally immature and enervated. A leisurely progress to Scots H.L.C. with studies continued on a broad front for four terms more, terminated by a selective examination would serve admirably.

My plea is really wider than the necessarily limited framework of this paper has so far suggested. Much is written about the failure to attract science teachers of calibre to school teaching. Many reasons for this are patent and are recognized ; but there remains a fundamental lack of appreciation of those values in science teaching which alone can command the lifetime devotion of the better type of science master. These values can hardly survive in a school system that is dominated and determined by an attainment test. If learning by rote reaps dividends, then lazy or merely uninformed teachers will be content to teach by rote ; but the training of understanding and the exercise of judgement is very much more demanding, both in the presentation of lessons and in the marking of homework and examination papers. Such teaching can only be supported by the recognition and public endorsement of the values it serves; by industry, government science and the universities. Such endorsement is less often given than might appear ; contemporary society values the fruits of the science masters' work rather than the work itself. In Scotland the present H.L.C. with its

endorsement of rote learning constitutes the most serious obstacle that the genuine science master meets. My case is not against the H.L.C. examination in itself—it is in fact an admirable attainment test ; what is essential to the well-being of young Scotland is the reinforcement of ultimate values in science teaching that would result from the provision of a selective examination at a more senior level in schools.

The breadth of the Scots course must be preserved, but variety of approach is essential. Imaginative, adventurous, liberal scientific education is crippled by the present higher leaving certificate course. First rate science staff are turned away from teaching because of this.

Young Scotland must be released from the unnecessary bondage of over much home-work and over-detailed study necessitated by the present over-loaded H.L.C. and given freedom to develop imaginative hobbies and leisure pursuits for their own and the communities' benefit and enrichment.

Physical Society Meetings

Members of the Institute are invited to attend the following Physical Society Meetings.

Sept. 26 — Acoustics Group

"*Sound Propagation in Solids*"
DR. J. W. F. BELL
At Imperial College, at 5.30 p.m.

Oct. 3 — Low Temperature Group

Reports on the fourth U.S.S.R. Low Temperature Meeting in Moscow, July, 1957
DR. R. BERMAN and DR. A. H. COOK

Oct. 3-4

"*Plasma and Atomic Physics*"
At the Atomic Energy Research Establishment, Harwell
Forms of application may be obtained from the Physical Society

Oct. 9 — Colour Group

"*Colour and Steelmaking*"
DR. B. O. SMITH
At the Royal Photographic Society, at 3.30 p.m.

Oct. 10 — Optical Group

"*Adhesives for Optical Instruments*"
MR. K. H. SPRING

"*Tolerances for Large Aberrations*"
DR. H. H. HOPKINS
At Imperial College, at 2.30 p.m.

Reviews of Books

INDUSTRY AND TECHNICAL PROGRESS

By C. F. Carter and B. R. Williams

London : Oxford University Press. Pp. 244 + viii. Price 25s.

As many readers of the *Bulletin* will be aware, this book, which has already been widely reviewed in the national press, is a report of an investigation of the hindrances to the speedy application of science in industry. The work was undertaken by the Science in Industry Committee, a body appointed by the Royal Society of Arts, the British Association, and the Nuffield Foundation and the report is written by its Directors of Research. The investigation relates particularly to the special problems of British industry although some of the conclusions may well be more generally applicable.

Most of us have our own ideas as to what are the important factors influencing the rate at which scientific advances are applied in industry, but there is, in general, only limited agreement as to what these are and probably few of us have analysed carefully just how and in what way these factors affect the situation. In this book a large number of the reasons often advanced are very deeply analysed and much relevant evidence is produced. The problem is treated both in general terms and also in terms of specific examples. The authors find that the factors influencing the speed of the application of science seem to them to be much more complex than is usually recognized—a conclusion that is amply supported by the evidence produced and which is deserving of the widest possible publicity. That many of their other conclusions appear almost self-evident—for example, that British industry is not universally backward in scientific matters but is uneven in its development—is unimportant : the value of the work lies largely in the detailed way in which each factor has been studied, and in the many, often unexpected, facets revealed by the analysis. There is, of course, no easy answer to the problem of ensuring the speedy application of science in industry and this book does not attempt to disguise this. Rather it seeks to expose as many as possible of the contributory factors in the hope that discussion of these will lead to action which will overcome some at least of the hindrances now existing.

The facts and arguments are, in general, well presented but the authors are obviously on more familiar ground when dealing with the economic and statistical aspects of the problem than when discussing the conduct or results of industrial research and development. Indeed, one is left very strongly with the impression that they regard the whole problem of the successful application of science in industry as one of arrangement and tend very much to underestimate the personal element. For example, their analysis of the reasons why, after the theory of semi-conductors had been developed in this country by A. H. Wilson, the transistor was invented in the U.S.A., probably does less than justice to the American physicists concerned. To pursue this point a little further, the attitude of industrial scientists themselves could well have been included amongst the factors investigated. The authors discuss the problem of the supply of trained men and women, but concentrate on quantity rather than on quality. Another aspect of the same problem which is not discussed is suggested by the observation that most of the specific examples cited relate to the older industries—pottery, textiles, cutlery. It is known that the proportion of turnover spent on research and development is greatest in the so-called "laboratory-based" industries — electronics, instruments, fine chemicals. Might it not be in the national interest (the authors' criterion) in a period of shortage of scientifically qualified people, to concentrate these where they are likely to show the best return rather than try to spread them thinly over the whole of industry ?

On matters of detail, the chief criticism

of the book is of the way in which the tables are arranged, the quantity tabulated being often only vaguely defined in the table itself. It is unfortunate too that more care was not taken with the jacket. The blurb here states that the book is " on the need for the rapid application of science and technology in British industry." This is not so. This need is assumed, with some reservation, on p. 2 and the book is concerned with the difficulties. Also, most readers will find the photograph on the front of the jacket rather puzzling. It happens to be a photograph taken in the reviewer's laboratory and he is still wondering which of the hindrances to the application of science it is supposed to illustrate ! There is no word of information (or acknowledgment) about it.

A. E. De Barr.

GENERAL RELATIVITY AND COSMOLOGY

By G. C. McVittie

London : Chapman & Hall Ltd. Pp. 198 + x. Price 42s.

This book by a well-known expert in the field is a welcome addition to the International Astrophysics Series, edited by M. A. Ellison and A. C. B. Lovell. The author succeeds in giving, in the restricted space of less than 200 pages, a very clear and readable account of the general theory of relativity and its bearing on cosmology. For readers who are not acquainted with the main mathematical tools of the theory, tensor calculus and Riemannian geometry, an introductory chapter on these topics is provided, and all basic assumptions are lucidly commented upon.

The general theory of relativity is essentially a continuum theory, and consequently the distribution of matter in space is considered to be continuous throughout in this book. It is furthermore assumed that this continuous distribution has the characteristics of a fluid. The chapter on Newtonian mechanics and special relativity therefore starts with a presentation of the Newtonian dynamics of fluids, and relativity mechanics is also restricted to fluids only ; nevertheless, a brief derivation of the relativistic equations of motion of particles, say, on the basis of the laws of conservation of momentum and energy, would have been desirable.

Of particular interest to astrophysicists are two chapters on relativistic gas dynamics which, among other things, deal with the problem of self-gravitation of a fluid and propagation of waves in fluids.

The last two chapters are devoted to problems of cosmology, in particular the problem of the recession of the galaxies. In order to make a systematic treatment mathematically feasible the actual system of galaxies is replaced by a perfect and uniform fluid in which density and matter are supposed to be constant in space but may depend on time in an arbitrary way, the so-called " uniform model universe." This contains the Einstein, de Sitter, and Lemaître universes as special cases. In principle it ought to be possible to find out from observations, mainly of the luminosity-redshift relation, which, if any, of the proposed models of this type represent the real universe to a fair approximation. But it seems, that at the present time the observational data are still too scanty for this purpose ; moreover, as pointed out by the author himself, the uniform model universe is actually too far removed from reality.

It is indeed doubtful whether the general theory of relativity in its original form will not need to be essentially modified in order to become compatible with the established discontinuous structure of matter.

R. Furth.

PROGRESS IN NUCLEAR ENERGY, SERIES VI ; BIOLOGICAL SCIENCES, VOL. 1

By J. C. Bugher, J. Coursaget and J. F. Loutit

London : Pergamon Press. Pp. 205 + x. Price 50s.

This is one of a series of volumes designed, according to the publishers, to bring " the significant matters of the Geneva Conference (on the Peaceful Uses of Atomic Energy) together in as compact a form as possible, so

that the material may have the widest availability. In this volume the reader will find distilled for him the essence of the discussions." The result, as might be expected, is a very strong drink, not altogether palatable, but which, taken in small quantities, could be stimulating.

Though not a book that will be of great use to a physicist, except if he is working close to the biological sciences, there is much in it that is of interest and importance to him as a scientist and as a citizen. There are eight sections and those on modes of radiation injury and on genetics will probably attract most attention. The bulk of the book takes the form of abstracts of the original papers, and though some are conflicting, no attempt is made to assess relative merits. An exception to this general pattern is the printing in full of the important contribution by H. J. Muller on "How radiation changes the genetic constitution." This still has great topicality and should be read by all who give thought to the problems of nuclear "experiments," be they in the Pacific or elsewhere.

Other chapters deal with the uses of radioactive isotopes in some agricultural problems, in plant nutrition, in plant and animal biochemistry and in mineral metabolism. In these, as in the earlier chapters, the physicist may find the going sometimes rather hard because of his unfamiliarity with the technical terms of the biologist. However, there is much to interest and even fascinate in the wide field of uses to which radioisotopes are now being put. These range from the measurements of the physical properties of soils using gamma ray sources to insect pest control by introducing enormous numbers of radiation-sterilized males into breeding grounds.

The reasonably adequate subject index could, with advantage, have been supplemented by an author index.

W. J. Meredith.

MAGNETOHYDRODYNAMICS

By T. G. Cowling

London and New York : Interscience Publishers Inc. Pp. 115 + viii. Price $3.50.

The behaviour of an electrically conducting fluid moving in the presence of a magnetic field is of wider interest than ever before. On a laboratory scale, investigation is difficult because of the ohmic resistance of convenient fluids and the necessarily small dimensions of the apparatus. Progress has been more rapid on the theoretical side. At first the applications were confined to astronomical problems such as sun-spots, the aurora and the general magnetic field of the sun. Now the equations are used in the study of confined, heavy-current discharges and in connection with the flow of liquid metals used to cool nuclear reactors.

The book begins with an introduction to the basic ideas of magnetohydrodynamics. Under particular conditions mechanical forces may be in equilibrium with magnetic forces and the second chapter shows how this can provide an explanation of the stability of sun-spots and solar prominences. An account of magnetohydrodynamic waves follows, with a summary of their application to theories of the formation of sun-spots. The fourth chapter is concerned with the effect of magnetic fields on turbulent flow and on thermal convection. The next chapter describes the efforts made to explain the earth's magnetic field by dynamo theories and the last is concerned with ionized gases and the effect of a magnetic field on the conductivity.

The clear argument, the reasoned criticism and the constant use of order-of-magnitude calculations make the book most stimulating to read. It is to be hoped that its publication will encourage further developments in this difficult but important field.

D. Dolbear.

PHYSICS IN METEOROLOGY

By A. C. Best

London : Sir Isaac Pitman & Sons Ltd. Pp. viii + 159. Price 18s.

Meteorology is often considered as a branch of physics ; in fact Humphreys' classic meteorological text-book is entitled *Physics of the Air*. One would therefore expect that the scope of *Physics in Meteorology* would include most aspects of meteorology, except possibly, weather forecasting. A glance at

the contents confirms this—there are chapters on Instruments ; Clouds ; Radiation ; Atmospheric Electricity ; Wind ; Meteorological Optics and Acoustics ; Radio-meteorology ; and finally, a brief account of the possibility of controlling the weather. A short list of references is given at the end of each chapter.

The text is carefully and accurately written, and a great deal of information is presented in a small space. Even so it is hardly possible to cover adequately such a wide range of subject-matter, and each chapter could easily be expanded to fill the book. For example, radio-meteorology is dealt with in twenty pages, and is limited to a theoretical discussion of anomalous propagation and attenuation due to water drops. Moreover there is no discussion of the thermodynamics of the atmosphere, and the important use of the temperature-entropy chart as a meteorological tool.

It is difficult to see for whom the book is intended to cater. The treatment is not detailed enough for the serious student, but on the other hand, is rather too heavy for the general reader, even if he has a knowledge of physics. There are only twenty-six diagrams, and the opportunity has been missed of enlivening the text with illustrations of some of the interesting and dramatic manifestations of physical processes, such as thunderstorms and cloud formations.

J. S. FORREST.

AN INTRODUCTION TO AUTOMATIC DIGITAL COMPUTERS

By R. K. Livesley

London : Cambridge University Press. Pp. 53 + viii. Price 8s. 6d.

This is the second book to be published in the new Cambridge Engineering Series. It is intended to help engineers and others who are faced with tedious calculations to judge what automatic calculating machines have to offer, and it is, in fact, based on a course of lectures first given to post-graduate apprentices in Metropolitan-Vickers Electrical Co. Ltd.

The author has succeeded admirably in his attempt to describe in general terms what digital computers do and how they do it. The account of the basic ideas of writing a programme is one of the most lucid the reveiwer has seen. The author describes the elements of programming, the various parts of an automatic machine, and how large programmes are built up from lesser prefabricated schemes. The final chapter reviews briefly some engineering problems to which computers have been directed in recent years. By avoiding details of any one machine and of particular circuits the author has produced a much-wanted introductory book. Two final attractions are that it can be read comfortably at one sitting, and so reasonable is the price it can be paid for in one instalment.

J. CRANK.

INTRODUCTION TO SOLID STATE PHYSICS

By Charles Kittel

London : Chapman & Hall Ltd. New York : John Wiley & Sons, Inc. Pp. 617 + xvii. Price 96s. (Second edition.)

This is a textbook for university students, covering a representative selection of aspects of the theory of the solid state. This edition is about one-half as long again as the first edition, the increased length being due partly to a fuller explanation of energy band theory, and partly to the addition of new material on alloys, semiconductors and imperfections in solids. Problems are included at the end of every chapter.

In the chapter on transistors some attempt has been made to link theory with practice by including photographs of transistors and of a furnace for growing germanium crystals, but these two illustrations seem to be out of place in a book which is inevitably devoted almost entirely to a discussion of the theory of simple models of solids. The general standard of the illustrations in the text is high and they indicate very clearly the extent of the agreement between theory and observation. Like the book as a whole, the diagrams and photographs are up-to-date and it is indeed refreshing to see, for example, a Laue pattern of a silicon crystal and a rotating-crystal photograph for sperm whale myoglobin illus-

trating the chapter on experimental X-ray diffraction methods.

Professor Kittel has himself made important contributions to solid state physics, and in his book he has provided the interesting and stimulating authoritative account that one would expect from a leading worker in the subject. It is the kind of book that could well be read by every undergraduate reading for a physics degree, whether specializing in solid state physics or not. It is, therefore, very much to be regretted that the price has increased so much since the first edition.

A. E. De Barr.

METROLOGY AND GAUGING

By S. A. J. Parsons

London : Macdonald & Evans Ltd. Pp. 285. Price 25s.

The author of this book was formerly head of the production engineering department at Birmingham College of Technology and is now Principal of Wellingborough Technical College. As one would expect, therefore, this book has been written mainly for engineering students and covers the syllabus requirements in metrology for the examinations leading to corporate membership of the Institutions of Mechanical Engineers and Production Engineers and also to the Higher National Certificates in mechanical and production engineering : typical examination questions are given in an Appendix.

The book deals adequately with the fundamental and working standards of length and the measurement of straightness and flatness. Other chapters deal with the interchangeability required in the mass production of engineering components, gauging principles and practice, and the design, manufacture, and inspection of limit gauges. Engineers' measuring instruments are described and also the measurement of surface texture. A valuable feature of the book is the frequent references made to relevant British Standards, but although reference is made to the British Standard *Definitions for use in Mechanical Engineering*, incorrect terminology has been used in several places.

Such fundamental measurements as those of flatness and straightness should have been described much earlier in the book than the penultimate chapter. Certainly they should have been described before the chapters on the measurement of gauges. In dealing with the Taylor principle of gauging also it is not made clear that the usual type of " Not Go " plug gauge may not control ovality and that, in theory, a " Not Go " pin gauge should be used.

The book includes a surprising amount of information, is very well illustrated and very reasonable in price. Bearing in mind the paucity of good up-to-date books on engineering metrology this book is to be recommended.

L. W. Nickols.

THE CATHODE RAY OSCILLOSCOPE

By J. Czech

London : Philips' Technical Library. Distributors for the United Kingdom and Eire : Cleaver-Hume Press Ltd. Pp. 340 + xii. Price 57s. 6d.

This admirable book gives a full and authoritative account of almost all the aspects of the design, operation and applications of the cathode ray oscilloscope. Part I deals with the construction of cathode ray tubes and the design of power supplies, time-base generators and deflection amplifiers. Part II on " General Measuring Technique " discusses the correct setting-up of the instrument, the measurement of amplitude, the use of the oscilloscope as a null indicator in a.c. bridge circuits, the display of hysteresis loops, the uses of intensity modulation, and phase and frequency measurements. Part III describes fully several practical examples of use, including investigations of television receivers, and Part IV is devoted to circuit designing.

Though the reader would need to have a knowledge of the fundamentals of electronics, he would require little preliminary information about the specialized circuits associated with oscilloscopes to understand the text. For example, the time-base generator is introduced in an elementary manner, and the subsequent accounts of gas triode circuits, linearization of the sweep voltage, the fly-back,

the multivibrator, the triple triode and triple pentode circuits, blocking oscillators and transitron circuits are described concisely but thoroughly and with the directly applicable mathematics.

Especially attractive features are the excellent diagrams, photographs of equipment and, in particular, the profusion of records of actual oscillograms. This latter feature could hardly be expected except in a work written by an authority and one with the equipment of the Philips' organization at his disposal.

A minor criticism of the work is that only oscilloscopes supplied by the Philips Co. are described. Admittedly, this covers a very wide range but there are several types of instrument (e.g. multi-gun tubes) available which have special and valuable uses. Details of these, even though they may only be supplied as special designs, would add to the value and the comprehensive nature of this useful book.

J. YARWOOD.

PHYSICS

By J. S. Marshall and E. R. Pounder

London : The Macmillan Co. Ltd. Pp. 906 + viii. Price 59s. 6d.

Intended for first and second year students at McGill University, this textbook offers a thorough treatment of elementary theory, some of which is presented in an unusual sequence, and much of which is given in an original way. Although the subject matter does not range considerably beyond what is usually taught in the upper forms of British schools, it is handled in a way which would appeal more to the intelligent undergraduate who will soon become a good physicist. And this is the kind of book that would help him to become one.

In the early chapters the principles of measurement, the idea of estimating accuracy, and the lengthy but safe Stroud method of inserting units throughout calculations lead on to the study of motion and equilibrium. The conservation laws are explained clearly, and the mechanical problems studied in some detail include the gyroscope, rockets, and the motion of the planets. The section on Heat strikes one at first as being rather a deductive exercise ; the kinetic theory of gases appears at once, and thermodynamics and heat engines are treated fully at an early stage. The use of a thermometer, apart from an excellent critical discussion of the principles of temperature measurement, hardly enters at all ; heat is measured (or rather calculated) in joules, and J only appears as a conversion factor to be used in working out certain sums. I am not criticizing this arrangement (I would leave that to people who may feel that dropping a 4·2 factor from formulae is an insidious offshoot of rationalization), for it seems that a clearer concept of heat as a form of energy may well be developed by treating it from the start as something to be accounted for solely in energy units. The reason given for the full treatment of Wave-motion, Sound, and Acoustics is the necessity for understanding waves thoroughly before going on to Light ; the way in which it is done suggests that this is really the field in which the authors' special interests lie. Wave-theory methods are used throughout the Light section, and the illustrative diagrams are most clear and helpful.

One point in the Electricity section (which is written throughout in rationalized m.k.s. units) made me wonder whether in fact the deductive treatment had been carried to excess—the presentation of Ohm's law as the *consequence* of two power relations I^2R (used to define R) and VI. This was sorted out satisfactorily later on, and the authors explained that this initial step was taken in the interests of generality. One cannot quarrel with its logic. Indeed, the same may be said of the book as a whole, which will certainly make the reader think for himself.

It is hard enough in the early stages to get pupils even to understand what is meant by a general principle and most elementary books aim at implanting this concept first, with a wealth of experimental description. The present book is for people who have passed this stage, or who are sufficiently mature in outlook to be able to follow an argument from general principles ; such readers should gain

from it a sound appreciation of the theoretical drill that they will apply later to more advanced work.

G. R. NOAKES.

ELECTRICITY AND MAGNETISM

By J. Newton

London : Sir Isaac Pitman & Sons Ltd. Pp. 613+ix. Price 25s.

This textbook is one of a series of four intended to meet the requirements of the Advanced Level G.C.E. and Intermediate examination in Physics. It should also be useful for university scholarship work and for the Ordinary National Certificate in Applied Physics.

Many well-known textbooks already cover this field, and the author is therefore to be congratulated on a work which adds significantly to what is already available. The outstanding impression conveyed is that of a very carefully considered presentation based upon acute sympathy for students' difficulties with fundamental and abstract concepts and gives evidence of considerable teaching experience. The writer has gone to considerable trouble to clarify fundamentals and present a continuous well substantiated argument throughout. Again and again traditional obscurities are illuminated because the author has thought it worthwhile to devote the space and detailed attention necessary.

Detailed consideration of electrostatics and magnetism is deferred to a later stage than is usual permitting of an earlier and more direct introduction to current electricity. This interesting approach achieves pleasing balance and continuity and forms a very readable introduction to the subject.

The author uses technical information most appropriately where this illustrates practice. In the chapter on Electrical power and resistance, for example, he gives useful information about wire sizes, current rating, fusing current, types of resistance, and the colour code. The same chapter, however, includes a thorough analysis of the effect of finite voltmeter resistance upon the measurement of potential difference. Thus balance is preserved and both theory and practice carefully described.

Most chapters include several clearly worked examples as well as the customary selection of examination questions given at the end of each chapter.

An introduction to the m.k.s. system of units is given in the chapter on Units, but the book as a whole uses the traditional older units.

More attention might perhaps have been devoted to modern physics. The clear but brief account given just meets Advanced level G.C.E. requirements. Also where so much valuable material is given students may find it difficult to distinguish between major and minor principles. Some sort of chapter summaries might have helped here.

The book as a whole, however, will be highly valued by the discriminating.

D. MCGILL.

Correspondence

Teaching electromagnetic theory

The controversy over the teaching of electromagnetic theory seems to be concerned mainly with such questions as what are the best fundamental units of measurement, and whether 4π should appear in this equation or in that. These are of course related to the more serious question of what is the best starting-point for the development of the theory, but they seem to me to be quite trivial in comparison with the unsatisfactory nature of the fundamental concepts of the theory, as revealed in recent discussions.

The concept of the magnetic pole has been mentioned. Now the fact that this does not correspond to a physically realizable entity is no doubt a strong objection to its use ; but at least it is something *conceivable*. On the other hand, a " current element " is not only unrealizable in the laboratory but, by me at least, cannot even be conceived as a physical entity. It is in fact a rather sophisticated mathematical abstraction. The formula for the field strength due to a current element is useful in calculations, but one cannot imagine any experiment which would verify it directly : one could only verify some integrated form of it. Yet I have heard it suggested, by one who regards the magnetic pole as a shibboleth, that this formula should be introduced to students as a fundamental physical law.

There is also a difficulty about flux. It is commonly held that this consists of lines of force (or of flux) " with their ends on electric charges, *one line per unit charge*" (I quote from Dr. Chalmers' article in the *Bulletin**—my italics). What sort of a concept is this ? I find it hard to imagine that it really means much to anyone. Certainly it does not correspond closely to the mathematical idea of a line of force, for there is one of these through every point at which the field strength is not zero. Surely Maxwell's idea of electric displacement, or ethereal strain, offers a better analogy than we can get from a tissue of isolated and emaciated threads ?

A good system of fundamental concepts seems to be urgently needed. Perhaps we ought to try to evolve one, instead of quibbling about units and dimensions.

J. D. Weston (*Associate*),
King's College, Newcastle upon Tyne.

Professor Lipson divides Institute members into those who agree with him and write to him, and those who disagree with him and write to the Institute.† I agree with him in some respects and disagree in others, but I hope he will forgive me if I write only to the Institute.

The use of metres, kilogrammes, amperes, etc., instead of centimetres, grammes, decamperes (the c.g.s.e.m. unit of current), etc., need not change the method of teaching electricity and magnetism. He who likes to start with electric and magnetic charges may still do so, the only change is in the units adopted for them ; having shown by experiment that the force between electric charges varies as their product and the inverse square of their distance apart, he tells the pupil that the constant of proportionality is chosen so that the coulomb and the ampere shall have the values fixed for them by international agreement : this constant is written $1/4\pi\varepsilon$ where ε is $8{\cdot}85 \times 10^{-12}$ in vacuum (he need not talk of " free space "), and only slightly greater in air. Similarly after he has shown by experiment that the law of the inverse square also holds good for magnetic poles (and this law can perfectly well be proved by working with long, thin magnets) he explains that μ must be given the value $1{\cdot}257 \times 10^{-6}$ in order that the unit magnetic flux defined by the formula shall be consistent with the electric units. Later, when the phenomenon of induction and the equivalence of the electric circuit and magnetic shell are demonstrated, the connection between the weber and the volt, itself linked to the ampere and the watt, becomes clear.

Later still Maxwell's equations are derived as in the past, but they now have simple forms :

$$\mathbf{curl\ H} = \dot{\mathbf{D}} + \mathbf{J}, \quad -\mathbf{curl\ E} = \dot{\mathbf{B}},$$
$$\mathbf{D} = \varepsilon\mathbf{E}, \quad \mathbf{B} = \mu\mathbf{H}, \quad \mathbf{J} = \gamma\mathbf{E},$$

and it is shown that the product $1/\varepsilon\mu$ is equal to the square of the velocity of propagation of electromagnetic waves. Now is the time to explain more fully the reasons for the choice of the constants, to outline if desired the history of our international units, and to point out the convenience of inserting a 4π in the denominator of the expressions for the forces. Is it more difficult for students to appreciate these arguments than to understand, as they would have been asked to in the past, why electric resistance has the dimensions of velocity in the electromagnetic system and those of the inverse of velocity in

**Bulletin*, Vol. 8 (June, 1957), page 207.
†*Bulletin*, Vol. 8 (June, 1957), page 206.

the electrostatic system ? I am not suggesting that the so-called " classical " method of teaching electromagnetism is the best but that the change from centimetres and grammes to metres and kilogrammes need not upset teaching.

I have published three books and many papers, not solely on electromagnetism, in which only the m.k.s. system is used, and am not aware that readers have experienced difficulties on that score. If any have I wish they would tell me, and why.

P. VIGOUREUX (*Fellow*).
Admiralty Research Laboratory,
Teddington.

Tuition by correspondence

The problems of education are receiving more attention now than ever before. The education of physicists is, naturally, the especial concern of this Institute and the proceedings of a recent conference have been fully reported in this *Bulletin* and have taken a large, but fair, share of four consecutive issues.* Neither there nor elsewhere have correspondence courses been mentioned, even though they play a considerable part in such education.

The London University external examinations have a long and honourable record of supplying senior scientists for industry, and a high proportion of these have obtained their instruction by correspondence, though this is never officially acknowledged. The instruction they could receive at evening classes was often not of the highest quality ; the pace was sometimes too fast but, more often, too slow ; and much of the syllabus would perforce have to be covered by private study. It is small wonder, then, that many of them found it pleasanter, easier and more efficient to carry out all their studies by their own firesides, after a rest and an adequate meal.

Our own experience taught us that lectures at a technical college, except under inspired teachers, were often a waste of time, and from talks with our younger colleagues, we have the impression that the situation is not always much different to-day. Indeed, we have heard the same criticisms made of the universities.

We would be the last to claim that there are no serious defects in commercial correspondence courses, but they do cover the syllabus and they do, with programmes of set work and frequent test-papers, keep the student at it.

Tuition by correspondence is the tutorial system working at long range. It suffers from lack of personal contact between tutor and student, and from the impossibility of laboratory work. But, it still retains two advantages of the tutorial system : one allows the student, within the framework of a long-term programme, to choose at each stage the pace that suits him best ; the other encourages him to learn to find out for himself and not to depend on having knowledge pumped into him.

We suggest that the increasing demand for scientific and technical education could be met by combining the best features of correspondence and personal tuition. We envisage a system in which the student would be given an assignment of work with test-papers at, say, monthly intervals. This could be sent to him by post from one of the larger colleges of technology. At similar intervals he would attend a local college for a tutorial session, either individually or as one of a small group, and for laboratory work if this was required.

It is our belief that a carefully designed system of this kind would be more satisfactory to most students, could give improved quality and, very important at present, could increase the rate of learning for many students and also the effective contribution of each teacher.

W. A. GURNEY (*Associate*),
C. H. LEIGH-DUGMORE (*Associate*).
Castle Bromwich, Birmingham.

* *Bulletin*, Vol. 8 (February, March, April and May, 1957).

News of Members

FELLOWS

A. W. Agar has taken up an appointment as head of Aeon Laboratories, Englefield Green, Egham.

J. N. Aldington has recently been appointed to the Board of Associated Electrical Industries Ltd. and has also been elected Chairman of Submarine Cables Ltd.

M. A. Cooper has taken up an appointment as Technical Adviser to S. A. Druggists Ltd., Johannesburg.

P. R. Coursey has retired as Technical Director of the Dubilier Condenser Co. Ltd., but will remain on the Board as an Ordinary Director.

J. R. Greening has moved to Edinburgh to become Director of the Medical Physics Unit established by Edinburgh University and the South East Scotland Regional Hospital Board.

V. G. W. Harrison has been appointed Director of Research of the Printing, Packaging and Allied Trades Research Association.

H. R. Hindley has taken up an appointment with Solartron Industrial Controls Ltd.

R. Jessel is now Chief Engineer of the Domestic Appliance Division of Thorn Electrical Industries Ltd.

A. J. Kennedy is now Professor of Materials and Metallurgy at The College of Aeronautics, Cranfield.

J. E. Keyston has taken up an appointment as Vice-Chairman of the Defence Research Board of Canada.

E. B. Moss has taken up a post as Technical Director of P.S.C. Applied Research Ltd., Toronto, Canada.

H. S. Peiser is now in the Constitution and Microstructure Section of the National Bureau of Standards, Washington, D.C.

D. Taylor has taken up an appointment with Plessey Nucleonics Ltd., Northampton.

R. W. White is now Assistant Staff Engineer in the Post Office Engineering Department.

ASSOCIATES

I. P. Bell has been promoted to Principal Scientific Officer with the United Kingdom Atomic Energy Authority.

R. E. Bentley is now with the Institute of Cancer Research at the Royal Marsden Hospital.

J. D. H. Bradley is now Senior Measurements Engineer with the English Electric Co. Ltd., Bradford.

J. A. Chaldecott has been appointed to the post of Deputy Keeper in the Department of Physics of the Science Museum and Secretary to the Advisory Council of the Science Museum.

W. E. Craker is now with the British Plaster Board (Holdings Ltd.) Research Department at East Leake.

N. Dickinson has taken up an appointment with the Atomic Energy Development Group of Ferranti Ltd., Manchester.

W. K. Dyer is now working as a Design and Development Engineer for the Hymatic Engineering Co. Ltd., Redditch.

F. H. East has been promoted to Senior Principal Scientific Officer and appointed Assistant Director of Air Armament Research and Development, Ministry of Supply.

D. R. R. Fair has been appointed Assistant Works Manager of the United Kingdom Atomic Energy Authority Nuclear Power Station at Chapelcross.

P. F. Hanson has been appointed Senior Lecturer in Physics at the Luton and South Bedfordshire College of Further Education.

R. Hardy is now with Imperial Chemical Industries Ltd., Alkali Division, Winnington.

R. Haynes has taken up an appointment with the Coil Spring Federation Research Organization, Sheffield.

W. C. A. Hutchinson has taken up a lectureship in of physics, Durham University.

P. E. Liley has been appointed to a professorship in the School of Mechanical Engineering at Purdue University, Lafayette, U.S.A.

W. H. Lunning has been appointed Manager of the Dounreay Materials Testing Reactor.

P. G. Parish has been promoted to Principal Scientific Officer with the United Kingdom Atomic Energy Authority.

D. W. Payn has joined Ferranti Ltd. at Bracknell.

N. Ramanathan has recently been appointed Senior Scientific Officer in the Physics Division of the Central Leather Research Institute, Madras.

D. D. Randall has joined the Vickers Group Research Establishment at Weybridge.

R. R. Ray has accepted a professorship in the Department of Physics at Pennsylvania State University, Pennsylvania, U.S.A.

G. H. Rees has been appointed Staff Project Research Member on the Proton Synchrotron which is being built by the Universities of Princeton and Pennsylvania.

K. W. Scott is now at the Madison Radiation Centre, Madison, America.

F. Stern has been appointed lecturer in Physics at the Royal College of Science and Technology, Glasgow.

A. P. Thatte has joined the Atomic Energy Establishment, Bombay, as a Scientific Officer.

W. Traub has taken a post in the Department of Biochemistry, College of Physicians and Surgeons, Columbia University, New York.

T. Wainwright has recently joined the Headquarters Staff, Scientific Department, National Coal Board.

K. W. Young is now with British Glues and Chemicals Ltd., Lancs.

GRADUATES

S. D. Chatar has been awarded a Shell Research Fellowship for research at the University of Malaya in 1956-57, and the 1956 Queen's Scholarship by the Government of the Federation of Malaya for research in the United Kingdom.

B. G. Dorrington has taken a post with A. E. Reed & Co. Ltd., Larkfield.

R. de P. Galloway is now employed as a Research Engineer at the E.M.I. Research Laboratories, Hayes.

R. Gordon has joined the Instrument Research Section of Imperial Chemical Industries Ltd. at Billingham as a Technical Officer.

R. A. Highfield is now a Technical Officer in the Experimental Spinning Section of the British Nylon Spinners Ltd.

C. H. Kelsey has joined the Division of Pure Physics, National Research Council, Ottawa.

J. Kirkhope is working in the Electronics and Instrument Development Department of Rolls-Royce Ltd., Aero-Engine Division Glasgow.

I. J. Macaulay has moved to Australia to join the Information Studio Group of the Weapons Research Establishment, Salisbury.

E. B. Page is now with Plessey Nucleonics Ltd., Northampton.

M. van Ments has taken up an appointment as a Work Study Engineer with the Metal Box Co. Ltd., London.

D. G. Wenham is now on the Experimental Staff of the Research Laboratories of The General Electric Co. Ltd., Wembley.

Forthcoming Institute Meetings

Sept. 23 Scottish Branch — At the University of Edinburgh, 7.15 p.m.
" *Recent Advances in Luminescence* "
PROFESSOR G. F. J. GARLICK, F.Inst.P.
(University of Hull)

Sept. 24 Scottish Branch — At the University of Glasgow, 7.15 p.m.
" *Recent Advances in Luminescence* "
PROFESSOR G. F. J. GARLICK, F.Inst.P.
(University of Hull)

Sept. 26-27 Yorkshire Branch and Non-Destructive Testing Group
In Stephenson Hall, Sheffield.
Joint Conference
Papers will be presented on " *Magnetism* " and " *Grain Boundary Problems in Metals* "
Forms of application may be obtained from the Deputy Secretary.

Sept. 27-28 Electronics Group — At the Brunel College of Technology, Acton.
Autumn Conference
Details and forms of application may be obtained from the Deputy Secretary.

Oct. 2 Education Group — At the Institute's House, 6 p.m.
Tea 5.30 p.m.
" *Mathematics in Physics Teaching and Research* "
DR. H. H. HOPKINS, F.Inst.P.
(Imperial College of Science and Technology)

Oct. 4 Liverpool and North Wales Branch — At the University of Liverpool, 7 p.m.
" *Radioactive Tracer Techniques* "
DR. F. D. S. BUTEMENT
(University of Liverpool)

Oct. 4 Stress Analysis Group
An all-day visit has been arranged to the Aeronautical Inspection Directorate Laboratories, Harefield.

Oct. 9 London and Home Counties Branch — At the Institute's House, 6 p.m.
Tea 5.30 p.m.
" *Physiological Effects of High Speed and High Altitude Flight* "
SQUADRON-LEADER R. S. WAMBEEK
(Royal Air Force Institute of Aviation Medicine)

Oct. 11 Manchester and District Branch — At the University of Manchester, 6.45 p.m.
" *Physical Methods of Dating in Archaeology and Geology* "
PROFESSOR F. E. ZEUNER
(University of London)

The Institute's Journals

PRINCIPAL CONTENTS OF THE SEPTEMBER, 1957, ISSUES

Journal of Scientific Instruments: Volume 34, No. 9

SPECIAL ARTICLE

Some new electrical and magnetic ceramics. By G. Campbell (*The Plessey Co. Ltd., Towcester, Northants.*).

These materials have been conveniently classified as insulator, conductor, ferroelectric and ferromagnetic ceramics. The functions of insulator and of conductor ceramics are readily understood and the underlying theory of conduction is briefly outlined. The ferroelectric and ferromagnetic classes are less widely appreciated : the analogies and the differences in these groups are discussed. The wide range of applications for these materials is indicated and some ceramics of particular interest to the electrical engineer and physicist are described more fully. These include ferroelectrics based on barium titanate for ceramic capacitors, piezoelectric transducers, dielectric amplifiers and memory devices. Other important ceramics are ferromagnetics based on soft magnetic ferrites for radio and television components, very high-frequency applications, magnetostrictive transducers, microwave components and memory devices together with ferromagnetics based on hard magnetic ferrites. Electronic devices and equipments of the future may use " solid " circuits made from various ceramic materials inert to moisture and capable of operating at relatively elevated temperatures.

ORIGINAL CONTRIBUTIONS

An optical probe for accurately measuring displacements of a reflecting surface. By K. W. T. Elliott and D. C. Wilson (*The National Physical Laboratory, Teddington, Middlesex*).

The probe described is capable of accurately measuring the displacement of a plane reflecting surface along its normal without making mechanical contact with it. The image of an illuminated grating of special construction is formed on the surface to be observed, and the light reflected from this surface then forms an image of equal size on a second, exactly similar, grating. The disposition of the second image relative to the second grating depends upon the position of the probe relative to the plane surface and changes in this disposition cause variations in the amount of light transmitted which are detected photo-electrically. It is therefore possible to set the probe at a reproducible distance from the reflecting surface by moving it until a predetermined level of light transmission is reached. Successive settings relative to a fixed surface indicate that the standard deviation of a single setting of the particular probe described is about $0{\cdot}4\mu$ ($1{\cdot}6 \times 10^{-5}$ in.). When the probe is used with a calibrated line standard, displacements may be measured with a standard deviation of $0{\cdot}7\mu$ ($2{\cdot}8 \times 10^{-5}$ in.).

The design of an apparatus for biological experiments at high hydrostatic pressure. By A. C. Downing and D. R. Wilkie (*Departments of Biophysics and Physiology, University College, London*).

A very simple and cheap design is described that can be used up to 1,000 atm. The stainless steel pressure chamber is provided with six insulated Pyrotenax leads and a permeability bridge for measuring mechanical changes. It has been used for recording the tension developed by a stimulated muscle but could be readily adapted to suit other experimental requirements.

Counter diffractometer—the effect of vertical divergence on the displacement and breadth of powder diffraction lines. By E. R. Pike, Grad.Inst.P. (*Viriamu Jones Laboratory, University College, Cardiff*).

The " vertical " divergence of the beam in a counter diffractometer causes a broadening, and a shift of centre of gravity, of diffraction lines. The effects do not disappear as 2θ tends to 180°, and hence present extrapolation methods fail to remove the errors introduced. Experimental results are quoted that are not explained by previous treatments, and a theoretical investigation is made of the diffractometer with no Soller slits, one set of slits, and two sets of slits. Results show a marked asymmetry about $2\theta = 90°$, both in shift of centre of gravity and in line broadening, the maximum effects occurring at low values of 2θ.

The use of Soller slits for various practical applications of the diffractometer is discussed. For accurate lattice-parameter measurement it is shown that the fractional error in spacing introduced by vertical divergence may be written in the form

$$\Delta d/d = -a + b\cos^2\theta$$

where a and b are positive constants depending on goniometer radius, specimen height, and Soller-slit

aperture (if used). Extrapolation against $\cos^2\theta$ and addition of the constant a will therefore give the true lattice spacing. The magnitude of the correction for a "Norelco" high-angle goniometer with two sets of Soller slits is approximately 4 parts in 10^5.

A new self-recording rheogoniometer. By A. F. H. Ward and P. Lord, A.Inst.P. (*Faculty of Technology, University of Manchester*).

A rheogoniometer of the cone-and-plate type has been designed, in which either a continuous rotation or a simple harmonic motion can be imposed on the cone. The torque transmitted through the fluid, and also the normal thrust between the plates, are measured by capacitance gauges. The torque, thrust and applied motion are shown on a c.r.o. screen and can be photographed.

Cooled photoconductive detectors using indium antimonide. By D. W. Goodwin (*Radar Research Establishment, Gt. Malvern, Worcs.*).

Improvement in the sensitivity of InSb photoconductive cells which operate at room temperature can be achieved under certain conditions by cooling cells to temperatures below ambient. Details of the performance of such cooled cells are given.

LABORATORY AND WORKSHOP NOTES

British Journal of Applied Physics: Volume 8, No. 9

ORIGINAL CONTRIBUTIONS

Electron micrographs from thick oxide layers on aluminium. By C. J. L. Booker, J. L. Wood (*Department of Chemistry, Sir John Cass College, London*) and A. Walsh (*Department of Applied Physics, Northampton College of Advanced Technology, London*).

Electron micrographs have been obtained of the pore structure in the thick oxide layer formed by anodizing aluminium in sulphuric acid. The pores are shown to be minute tubes of approximately 200 Å diameter running perpendicularly through the oxide and ending almost in contact with the underlying metal. The pore base thickness has been estimated, and the effect of a change in anodizing conditions on the pore base pattern is shown.

Barium getters and carbon monoxide. By R. N. Bloomer (*Research Laboratory, Associated Electrical Industries Ltd., Aldermaston, Berks.*).

The absorption of carbon monoxide by evaporated barium films has been studied in a pressure range 10^{-6} – 10^{-7} mm. of mercury. The mechanism is shown to be similar to that for oxygen (Bloomer), and is explained with the aid of Mott's theory. Carbon monoxide is dissociated at the surface of the barium film, and an oxide layer containing free carbon is formed. Below 80°C., the layer of reaction products is protective once it has grown to a thickness of about 50 Å. Above, 80°C., the whole of the barium is used up in the reaction.
The condensation coefficient at room temperature is 0·012. Thus about 1 in 80 of the carbon monoxide molecules striking the getter surface in any period is taken up by a barium film at room temperature (1 in 40 at 170°C.). The condensation coefficient is limited to these low values by the superficial density of interstitial barium ions in the free surface of the oxide layer. A nearby ionizing discharge has very little influence upon the fraction of incident molecules which is condensed upon and taken up by a barium film.

A system for recording transmission errors in universal joints. By A. J. Bartley and R. W. Gregory (*Department of Mechanical Engineering, University of Durham*).

This paper describes the development of a new system for recording the "performance characteristics" of universal joints. The system is described in detail and some test results obtained with a single Hooke's joint are included. The system could also be used for recording the twist in a shaft subject to torque and would be most suitable for use on shafts where the twist is to be measured over two reference points which are so remote from each other that more conventional systems could not be used.

The effect of oxygen and sulphur on the thermionic emission from matrix cathodes. By J. F. Richardson, Grad.Inst.P. (*Physics Department, University College of North Staffordshire*).

The poisoning of the emission from matrix cathodes by oxygen and sulphur is reversible. Recovery of the emission is more rapid from oxygen poisoning. The shape of the recovery curves indicates that the poisoning agent is present on the surface and has also diffused into the cathode pores.

The ageing of gasfilled standard lamps on a.c. and d.c. By W. Barnett, R. G. Berry, and J. S. Preston, F.Inst.P. (*Light Division, National Physical Laboratory, Teddington, Middlesex*).

A comparison is made of the rates of fall of light output and current, at constant voltage, and colour temperature 2700° K approx., of 100–110 V 100 W gas-filled photometric standard lamps, on a.c. and d.c. supplies. The rates are appreciably greater on d.c. than on a.c., and this is shown to be due to specific effects of d.c.-operation on filament resistance, and filament emissivity. These effects are shown to be fully reversible, after many hours of burning, by reversal of the d.c. polarity, and not inconsistent with migration of tungsten along the surface of the filament. A practical conclusion is that the usefully smaller rate of depreciation characteristic of a.c.-operation may be fully retained on d.c. by reversal of polarity at regular convenient intervals. An a.c. supply, with its easy voltage regulation, is then legitimate for burning the lamps for the lengthy periods of the normal preliminary ageing tests.

The use of low-inertia integrating motors. By R. F. Farr, F.Inst.P. (*Department of Clinical Physics, Christie Hospital and Holt Radium Institute, Manchester 20*).

The relative advantages and the performance of these small permanent-magnet motors which have, over a certain range, a speed proportional to the applied voltage, are discussed. The current-voltage characteristics, which allow the motor to be described by a simple equivalent circuit, are used to derive the speed-voltage characteristic when it is driven by a voltage source of appreciable internal resistance. Choice of the type of motor is discussed in relation to the integration of relatively large and of small voltages.

An iterative analogue computer for use with resistance network analogues. By I. C. Hutcheon (*Research and Development Department, George Kent Ltd., Luton, Beds.*).

When field problems involving sources or sinks are solved using resistance network analogues, currents must be applied to the nodes of the network such that each current is a desired function of the associated node potential.
This requires repeated re-adjustment of every current until each is correct. A method is described whereby the adjustments are made automatically by a scanning switch, a function generator, an a.c. amplifier, and a set of triode valves each connected to a network node and having a memory capacitor connected to its grid. The solution is thus achieved rapidly, and changing problems can be solved continuously.
Suitably modified, the apparatus may find uses such as solving other differential equations or providing a set of non-linear resistors for fluid flow analogues.

The optical density and thickness of evaporated carbon films. By Anna Cosslett, and V. E. Cosslett, F.Inst.P. (*Cavendish Laboratory, Cambridge*).

Measurements of the variation in optical density with thickness of evaporated carbon films (50–1500 Å thick) give a value of the absorption coefficient considerably lower than that recently found by Agar. Our mean value is close to that for natural graphite and electron diffraction patterns suggest that the films consist of randomly orientated graphite lamellae of varying width embedded in a variable amount of amorphous carbon. The optical density of films of the same nominal thickness may vary as much as 25%, probably due to variations in the degree of orientation of the lamellae and in their lateral extension. The much greater difference (60%) between our films and those of Agar is ascribable to more radical differences in the method of evaporating and collecting the carbon. This dependence of optical properties on method of preparation means that there can be no universally valid calibration curve for finding film thickness from optical density. The method proposed by Agar is reliable only if the details of preparation are standardized and a calibration curve is produced for each set of conditions.

On the mechanism of the production of dark-current pulses in photomultipliers. By Zs. Naray and P. Varga (*Central Research Institute of Physics, Budapest, Hungary*).

It was found that the dark-current pulses of photomultipliers are chiefly produced by the particles emerging from the glass envelope, i.e. if the envelope is at a more negative potential than the cathode, electrons are emitted by the envelope, and if the envelope is at a more positive potential than the cathode the electrons—produce scintillations in the glass envelope and a photon feedback takes place. By this mechanism the fact that the shield has a greater effect on the dark-current pulses of higher amplitudes can be satisfactorily explained.

CORRESPONDENCE

MIDDLESEX COUNTY COUNCIL
EDUCATION COMMITTEE

BRUNEL COLLEGE OF TECHNOLOGY,
WOODLANDS AVENUE, ACTON, W.3

Required, Senior Lecturer in Physics. Candidates should have a good degree in physics, and industrial, research and teaching experience. Special interest in some branch of applied physics desirable.

There is an opportunity to undertake research and to contribute to the development of sandwich courses for the Diploma in Technology. Salary in accordance with the Burnham (Technical) Report, 1956, i.e. Senior Lecturer —£1,350 × £50–£1,550 p.a. plus London allowance.

Further particulars and forms of application (stamped addressed foolscap envelope) from the Clerk to the Governing Body, Brunel College of Technology, to whom completed forms must be returned within 14 days of the appearance of this advertisement.

C. E. Gurr, M.Sc., Ph.D.

Secretary to the Education Committee

EXPERIMENTAL/ASSISTANT
EXPERIMENTAL OFFICERS
required by
THE ATOMIC WEAPONS RESEARCH
ESTABLISHMENT
ALDERMASTON, BERKSHIRE

for work in the following fields :

(*a*) Mass Spectrometry—development of new machines and techniques using commercial machines ;

(*b*) Radioactivity Investigations—analysis of radioactive species, development of techniques for the detection and analysis of nuclear radiation and research into radioactive decay schemes. Excellent equipment available ;

(*c*) High Vacuum techniques and gas chromatrographic investigations.

G.C.E. in five subjects including physics and mathematics at advanced level, or equivalent, is the minimum qualification, although an ordinary or pass degree is desirable. Experience in the above fields or in electronics an advantage.

Applicants for the E.O. posts should be at least 26 years of age.

Salary : E.O. £990 – £1,215 p.a. (male) ;
A.E.O. £395 (at age 18) – £700 (at age 26 or over) – £855 p.a. (male).

Contributory superannuation scheme. A house or assistance towards legal expenses on house purchase will be available for married officers living beyond daily travelling distance.

Postcards for application forms to the Senior Recruitment Officer at above address. Please quote ref. 1573/110.

THE ELECTRICAL RESEARCH ASSOCIATION invites applications from honours graduate physicists (or electrical engineers and chemists with a strong interest in the physical aspects of their subjects) for posts in their Properties of Materials Department. Applicants who have recently obtained a Ph.D. degree are preferred, and for these the initial salary is £900 p.a. A somewhat higher salary may exceptionally be offered. Any applicant with a good academic record and a strong interest in research will, however, be considered.

Those accepted will engage in basic research into the electrical properties of dielectrics, especially the properties of oxide films on metals, and the inception of ionic discharges in liquids. Some weight can be given to the individual interests of applicants, who if not accepted for these posts will also be considered for vacancies existing in other departments covering a wide range of electrical research.

Employment will be at the newly built and well equipped laboratories of the Association at Leatherhead, Surrey. The appointments will be to the permanent research staff, with superannuation under the F.S.S.U. The Association expects to expand its activities on its new site, and good prospects exist for men capable of original research and initiative. Applications should be addressed to The Director, E.R.A. Laboratory, Cleeve Road, Leatherhead, Surrey.

THE BRITISH THOMSON-HOUSTON CO. LTD., has vacancies in its Lamp Engineering Department for scientists and technical assistants for all aspects of work (physics, chemistry and engineering) connected with the development of electric filament and discharge lamps. The work offers interesting careers at various levels to those with qualifications ranging from an honours degree to O.N.C., and will be either at Leicester or in the north London area. Applicants are invited to write to the Manager, Lamp Engineering Department, The British Thomson-Houston Co. Ltd., Rugby, giving details of their age, qualifications and experience, quoting reference TA.

AUSTRALIA

UNIVERSITY OF QUEENSLAND

Applications are invited for the position of Senior Lecturer in Physics. Applicants should possess a doctorate of philosophy or science, conferred for research in some branch of physics. It is desirable, but not essential, that he should have had some lecturing experience.

Salary £A1,850–£A2,150 p.a.

Further particulars are obtainable from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close in Australia and London on September 30, 1957.

Chartered Patent Agents

W. H. BECK, GREENER & CO.

7 Stone Buildings,
Lincoln's Inn,
Chancery 2535 London, W.C.2

THE HOSIERY AND ALLIED TRADES RESEARCH ASSOCIATION

Applications are invited for :

STATISTICIAN

Candidates should possess a degree in statistics or mathematics. The person appointed would deal with a wide range of problems in fundamental and industrial research, calling for the use of varied statistical and mathematical techniques.

PHYSICIST

There is a vacancy for a graduate in the physics department. Applicants must have a degree or equivalent qualification. Research and/or industrial experience is desirable.

The work, which is concerned with various aspects of the manufacture and properties of knitted products, is interesting and there are good prospects of further advancement.

Initial salary for both posts within the range £700–£1,000 per annum, according to qualifications and experience, with superannuation benefits under the Federated Superannuation System for Universities.

Applications should be addressed to the Secretary, Hosiery and Allied Trades Research Association, 4 First Avenue, Sherwood Rise, Nottingham.

NORTH STAFFORDSHIRE TECHNICAL COLLEGE

STOKE-ON-TRENT

Principal : H. W. Webb, O.B.E., D.Sc.

PHYSICS DEPARTMENT

Applications are invited for the post of full-time Lecturer in Physics. Candidates should have a good physics degree or be corporate members of the Institute of Physics, and should preferably have had teaching experience.

In addition to a general interest in all branches of physics and in its applications in industry, candidates should, if possible, have some particular interest and experience in a special subject ; for example : industrial instrumentation including automatic control, electronics, spectroscopy, X-ray diffraction, photography, nuclear physics, etc. Applicants should expect to be asked to teach some branches of pure and applied physics up to Higher National Certificate standard.

Burnham Technical Scale of salaries : £1,200 × £30 – £1,350 per annum.

Applications giving details of age, qualifications, training and experience, together with the names of two referees, should be sent to the Principal, as early as possible and in any case not later than September 21, 1957.

H. Dibden,
Clerk to the Governors.

THE COLLEGE OF AERONAUTICS

Physicist/Metallurgist required in materials and metallurgy section to lead a research project on the fatigue properties of light alloys. Applicants should possess a good engineering or science degree or equivalent. Salary up to £1,250 per annum, depending on qualifications and experience, with superannuation under F.S.S.U., and family allowance. Applications giving full particulars and containing the names of three referees, to the Recorder, The College of Aeronautics, Cranfield, Bletchley, Bucks. Further particulars available.

THE NATIONAL COAL BOARD, South Western Division, invite applications for the post of Physicist at the Board's Divisional Laboratory, Ystrad Mynach, Nr. Cardiff.

The work consists mainly in the application of physical methods to the testing of mine air and other gases, and to the recording and controlling of methane from methane drainage schemes.

Candidates should possess a good honours degree in physics, with mathematics and/or statistics, and should preferably have had industrial experience. The successful applicant will be graded as Scientist Grade II or III according to qualifications and experience. The post is superannuable.

Salary scale :

Grade II : £975 × £35 – £1,360 per annum
Grade III : £630 × £30 – £1,110 per annum.

Please quote staff vacancy No. 407.

Full particulars of age, qualifications, experience and positions held should be sent to the Divisional Chief Staff Officer, National Coal Board, Cambrian Buildings, Mount Stuart Square, Cardiff, by September 18, 1957.

GSI LTD., large Geophysical Company expanding in the Eastern Hemisphere, requires Graduates with honours degree in geophysics, geology, mathematics, physics or electrical engineering. Generous salary, bonus and living allowance. Write details of age, marital status, education and experience to GSI Ltd., Eagle Chambers, Rosehill Court, Morden, Surrey.

A PHYSICIST or an ELECTRONICS ENGINEER is required for research on Non-Destructive Testing of materials and welded joints at the British Welding Research Association laboratories near Cambridge. The post offers unique facilities for contact with British and European specialists in this field, and opportunities for collaboration with other research workers in metal fatigue, brittle fracture and welding metallurgy. Salary in Senior Research Officer grade £900 – £1,300. Superannuation under F.S.S.U. scheme. Apply with full particulars of education and experience to the Secretary, B.W.R.A., Abington Hall, Abington, Near Cambridge.

DIRECTOR OF HYDRAULICS RESEARCH.

Department of Scientific and Industrial Research. The Civil Service Commissioners invite applications for this pensionable post at Howbery Park, Wallingford, Berks.

The research programme embraces " loose boundary " hydraulics and associated civil engineering problems, affecting docks and harbours, canals and rivers, coast protection and land-drainage and reclamation. The total staff is at present about 140.

Candidates should have high scientific or professional engineering qualifications ; those without high formal qualifications but with high professional attainments may be admitted. All candidates must have had extensive experience of research and the organization of research in physical or civil engineering science.

The salary scale is £2,400 – £2,700. For a woman it is at present somewhat less.

Further particulars and application forms from Civil Service Commission, Scientific Branch, 30 Burlington Street, London, W.1, quoting No. S4755/57. Application forms should be returned not later than October 10, 1957.

INDUSTRIAL ELECTRONICS

There are two vacancies in London for senior engineers to lead small teams engaged on a variety of electronic projects.

(1) Senior Electronic Engineer to handle industrial problems from initial enquiries through development, to final engineering.

(2) Engineer-Physicist to work on technical investigations and special design problems.

Applicants should have a degree in engineering or physics, and for post (1) should preferably have had practical experience. These interesting posts in a new and expanding department will carry an initial salary of £1,000 to £1,500 and offer excellent prospects. Good technical and library facilities, and the resources of a large company are available. Write giving details of education and experience to The Personnel Officer, The Plessey Co. Ltd., Ilford, Essex.

BRITISH PETROLEUM CO. LTD., has vacancies for Geophysicists on its exploration staff. Candidates who should have some experience in the field and must have an honours degree in physics with subsidiary mathematics and/or Geology. Basic salary is commensurate with age and experience, commencing at £1,130 for young inexperienced graduates. Appropriate allowances are paid on foreign service. Generous pension scheme. Written applications, quoting reference F.533 should be addressed to Personnel Manager, British Petroleum Co. Ltd., Britannic House, Finsbury Circus, London, E.C.2.

SENIOR SCIENTIFIC OFFICERS and Scientific Officers required in Department of Scientific Adviser to Air Ministry. Candidates should have degree in mathematics, science or engineering with 1st or 2nd class honours or equivalent. Appointments offer wide scope and great interest, particularly at present time, to versatile scientists capable of working well with serving officers and of adopting methods suited to service environment. Work is mainly operational research in wide variety of subjects of concern to Royal Air Force, including tactics, technical development and logistics. Salary (London) £1,135–£1,345 (S.S.O. men) and £605–£1,055 (S.O. men) under review. Provincial rates and rates for women slightly lower. Good prospects of promotion. Forms from M.L.N.S. Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A33/7A.

CENTRAL ELECTRICITY AUTHORITY

RESEARCH LABORATORIES, LEATHERHEAD, SURREY

PHYSICIST

Physicist required to work on X-ray diffraction. Candidates should have a degree or equivalent with experience in crystallography, vacuum techniques, X- or gamma-radiography or photography.

Salary within the scale £820–£995 per annum.

Applications stating age, experience, qualifications and present position and salary should be forwarded to D. Moffat, Director of Establishments, Central Electricity Authority, Winsley Street, London, W.1, as soon as possible. Quote ref. B.I.P./347.

STANDARD TELEPHONES AND CABLES LIMITED

Applications are invited for the Transistor Division :

1. **Senior Scientists.** Physicists and Electrical Engineers for work on fundamental concepts in solid state physics and S-C device design. Good honours degree (a higher degree may be preferred) and some research and/or industrial experience essential.
2. **Mathematicians** (male or female) to work for above group and device development and application department. Honours degree essential.
3. **Physicists and Electrical Engineers.** B.Sc. or equivalent for device development department. These posts will also suit postgraduates without previous experience.

Attractive salaries are being offered and terms and conditions of service at this " garden " site, within easy reach of Charing Cross, are excellent. Applicants should write with brief details in confidence to :

W. J. Yeomans, Personnel Manager,
Standard Telephones and Cables Ltd.,
Footscray, Sidcup, Kent.

UNIVERSITY OF DURHAM

KING'S COLLEGE, NEWCASTLE-UPON-TYNE

Senior Research Assistant in Physics required for research programme on paramagnetic resonance in semiconductors. Candidates should have a Ph.D. in physics and preferably several years' additional research experience in solid state or magnetic resonance problems. Salary up to £1,000 per annum plus F.S.S.U. depending on age and qualifications.

Applications, together with the names of two referees, should be submitted as soon as possible to the undersigned from whom further particulars may be obtained.

G. R. Hanson,
Registrar of King's College

AUSTRALIA—UNIVERSITY OF TASMANIA

The University invites applications for the position of Lecturer in Mathematics. It is desirable that applicants should have qualifications in Applied Mathematics.

The salary scale is £A1,500–£A1,750 with annual increments of £50. An allowance is made towards travelling expenses and housing assistance is available. Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

The closing date for the receipt of applications, in Australia and London, is October 31, 1957.

MATHEMATICAL PHYSICISTS OR MATHEMATICIANS

required by

THE ATOMIC WEAPONS RESEARCH ESTABLISHMENT, ALDERMASTON, BERKSHIRE

in the grades of

Principal Scientific/Senior Scientific/Scientific Officer to work in one of the following fields :
Astrophysics, atmospheric diffusion, stochastic theory, statistical, fluid, solid or general applied mechanics, numerical analysis for large digital computers.
1st or 2nd class honours degree in mathematics or mathematical physics required with preferably some years' postgraduate research experience in one of the above or allied fields.

Salary : P.S.O. £1,460–£2,080 p.a.
S.S.O. £1,215–£1,425 p.a.
S.O. To be assessed according to age, qualifications and experience within the scale £645–£1,120 p.a.

Contributory superannuation scheme. A house or assistance towards legal expenses on house purchase will be available for married officers living beyond daily travelling distance.

Postcards for application forms to the Senior Recruitment Officer at above address. Please quote ref. 1580/110.

THE COLLEGE OF AERONAUTICS

Research Assistant required in materials and metallurgy section for work associated with the fatigue of light alloys. Both laboratory and workshop experience desirable. Applicants with a good engineering qualification preferred. Salary up to £800 per annum, depending on qualifications and experience, with superannuation under F.S.S.U., and family allowance. Applications giving full particulars and containing the names of three referees, to the Recorder, The College of Aeronautics, Cranfield, Bletchley, Bucks.

TECHNICIANS

SENIOR LABORATORY ASSISTANT (female) preferably with H.N.C. or O.N.C. in applied physics, required at the Research Laboratories of The British Aluminium Co. Ltd., Chalfont Park, Gerrards Cross, Bucks. Work in the group concerned covers measurements of physical properties, X-ray diffraction, electron microscopy and metallography. Salary in accordance with qualifications and experience. Apply in writing to the Director of Research at the above address.

SENIOR LABORATORY STEWARD in the Physics Department wanted at once. New buildings nearing completion, containing seven laboratories and four lecture rooms. Up-to-date workshop with modern equipment. Applications stating age, qualifications and experience to the Receiver, Manchester Grammar School, Manchester, 13, from whom further particulars may be obtained.

Physics in Industry Series

PHYSICS OF FIBRES

AN INTRODUCTORY SURVEY

BY

H. J. Woods, M.A., F.Inst.P.

Lecturer in Textile Physics, University of Leeds

The emphasis throughout this book is on the natural rather than the man-made fibres, but anyone who knows something about cellulose and keratin will find little difficulty with other fibres. The author's object has been to provide an introduction to the subject for scientists commencing research and development work in this field by indicating the lines along which the physical approach to the study of the structure and properties of fibres has proceeded.
He has also had in mind the scientists whose interests are in other fields, but who may wish to learn something about the ways in which physics has helped in advancing our knowledge of fibres.
A bibliography and fairly full list of references have been provided for those who wish to pursue the subject further.

price 30s. including postage, to members of the Institute 25s.

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Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

BRITISH PETROLEUM CO. LTD., have a vacancy in the geophysical section of their Research Station, for a Physicist with an honours degree and at least two years' research experience. Some knowledge and experience of high-voltage pulse techniques is very desirable. Whilst direct experience in applied geophysics is not essential, it would be considered an advantage. The candidate should be a versatile physicist with a sound fundamental knowledge, capable of working on a variety of problems which arise in connection with various methods of geophysical surveying. Excellent working conditions. Non-contributory pension scheme. Write giving full details, quoting H.3597 to The Manager, Recruitment Branch, The British Petroleum Co. Ltd., Britannic House, Finsbury Circus, London, E.C.2.

BRITISH THOMSON-HOUSTON CO. LTD.

The British Thomson-Houston Co. Ltd. has vacancies in an expanding research group working on problems associated with the applications of semiconducting materials. There are vacancies for physicists with good honours degrees, technicians with H.N.C. or G.C.E. A level and a mathematical physicist. The successful applicant for the latter post would be concerned with the analysis of data and also the application of theoretical physics to the search for new semiconducting materials and devices.

The positions are pensionable and offer excellent prospects.

Applicants are invited to write to the Director of Research, The British Thomson-Houston Co. Ltd., Rugby, stating age, qualifications and experience and quoting reference W.1.

Several attractive and Senior Positions are offered in the Development and Industrial application of modern non-destructive testing techniques. The positions will be in the following fields :

(1) Electronic Circuit Development
(2) Properties of Materials
(3) Physical Investigation and Measurement

They offer good scope to men of initiative and experience in the above fields. Salaries will be commensurate with the candidate's qualifications and experience.

Applications should be made in writing in the first instance, giving full details of qualifications, previous experience, age and salary required to : Personnel Manager, Kelvin & Hughes Ltd., New North Road, Barkingside, Essex.

GSI LTD., large Geophysical Company expanding in the Eastern Hemisphere, requires Graduates with honours degree in geophysics, geology, mathematics, physics or electrical engineering. Generous salary, bonus and living allowance. Write details of age, marital status, education and experience to GSI Ltd., Eagle Chambers, Rosehill Court, Morden, Surrey.

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG,
SOUTH AFRICA

Applications are invited for appointment to the posts of Senior Lecturer and Lecturer on the staff of the Department of Physics. Salary scales : Senior Lecturer : £1,200 × 50–£1,500. Lecturer : £850 × 50–£1,200.

Cost of living allowance : Payable in terms of Union Government regulations to persons with dependants. The present rate for a married man is £234 per annum.

A Senior Lecturer in Physics, after he has reached the top of the salary scale may be eligible for an additional special increment of £100 per annum bringing the maximum salary to £1,600 per annum.

The University, which has almost 5,000 students, is sited in the heart of the largest industrial and mining area in Africa, in pleasant surroundings with a particularly healthy climate.

Membership of the University Insitutions Provident Fund is compulsory and involves a contribution at the rate of 7 per cent of the salary paid. Membership of the Staff Medical Aid Fund is obligatory in the case of an officer who is eligible for membership in terms of the rules of the Fund.

Applicants are advised to obtain a copy of the information sheet relating to these vacancies from the Secretary Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

Applications close in South Africa and London on November 1, 1957.

INTERNATIONAL UNION OF CRYSTALLOGRAPHY
ASSISTANT EDITOR OF STRUCTURE REPORTS

Applications for the above post will be considered from candidates with either (*a*) a good knowledge of languages, including Russian, and some acquaintance with chemical terminology, or (*b*) a good knowledge of physics or chemistry or mineralogy, and some acquaintance with European languages. Salary £700 (age under 26) or £750 (age 26 or over) × £50–£850. Existing F.S.S.U. will be continued. Place of work—Cardiff. Applications (three copies) to Professor A. J. C. Wilson, University College, Cardiff, from whom further details may be obtained.

SIEMENS EDISON SWAN RESEARCH LABORATORY

A senior post in Transistor Research in the new Siemens Edison Swan Research Laboratory, Harlow, Essex. Required a senior physicist to take full charge of research on transistors and related matters. The post offers excellent prospects and a wide scope for planning and achievement. Housing available. Write for application form to : Personnel Officer, Siemens Edison Swan Research Laboratory, West Road, Templefields, Harlow, Essex.

COMMONWEALTH OF AUSTRALIA

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION

DIVISION OF METROLOGY

APPOINTMENT NO. 750/155 OF RESEARCH PHYCISIST

Applications are invited for appointment to a position of Research Physicist with the Interferometry Section of the Organization's Division of Metrology located in the grounds of the University of Sydney, New South Wales.

The Interferometry Section is engaged on research in interferometry and thin films, and the application of interferometric techniques to the measurement of length and vibration, and to the study of the mechanical and optical properties of surfaces such as surface structure, hardness, adhesion and optical phase change at reflection. The appointee will be required to take an active part in aspects of this programme.

Applicants should possess a University honours degree in physics or equivalent qualifications, preferably to Ph.D. standard, together with some years of appropriate postgraduate research experience.

Commencing salary is dependent upon the appointee's qualifications and experience and will be determined within the salary ranges of Research Officer £A1,313–£A1,938 p.a., or Senior Research Officer, £A2,048–£A2,323 p.a. The Appointment, which will be for a period of three years, is conditional upon a satisfactory medical examination. In the case of the appointee domiciled overseas, first-class sea fares to Australia will be paid for the appointee, his wife and family. At the end of the period of appointment return fares will also be paid.

A Senior Officer of the Division will be in the United Kingdom from November to February next and for further information regarding this appointment he may be consulted at the Australian Scientific Liaison Office.

Applications quoting Appointment No. 750/155 and stating full name, place, date and year of birth, nationality, marital state, present employment, particulars of qualifications and experience, and of war service, if any, accompanied by copies of not more than four testimonials, and the names and addresses of three persons willing to act as referees should reach the undersigned, from whom further particulars may be obtained, by November 8, 1957.

A. Shavitsky
(Chief Scientific Liaison Officer)
Australian Scientific Liaison Office,
Africa House,
Kingsway,
London, W.C.2.

NATIONAL COLLEGE OF FOOD TECHNOLOGY

CRANWOOD STREET, CITY ROAD, LONDON, E.C.1

The Governors invite applications from physics graduates for the post of Assistant Lecturer in the College. Salary scale : £775 × £25–£1,150. Previous experience of teaching desirable. The post is pensionable under the Teachers' Superannuation Acts. The successful candidate will be expected to assist with the development of the new four-year Sandwich course in Food Technology.

Application forms (obtainable from the College) should be sent to the Principal as soon as possible.

PHYSICIST, graduate required for the research laboratories of British Insulated Callender's Cables Ltd., Shepherds Bush, London, W.12. The work involves research and development of vacuum metallizing processes, instrumentation and measurement of electrical properties of capacitor components. Special experience in vacuum technology would be desirable but is not essential. Five-day week. Pension Fund. Applications giving details of age, qualifications and experience should be made to Manager (Personnel), BICC Ltd., Norfolk House, Norfolk Street, London, W.C.2, reference W.L.13.

PHYSICISTS

are required by the

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

to fill posts in the Operations Branch at the Industrial Group Headquarters, Risley, Warrington, and at their Works at Windscale at Calder in Cumberland and at Chapelcross, Annan, Dumfriesshire.

Applicants must have a good degree in, or including Physics, or have equivalent qualifications. Successful candidates will receive training in various aspects of reactor operation or Health Physics. These posts provide excellent opportunities for those keen to pursue a career in the Industrial application of Atomic Energy.

Salary will be assessed within the range £815 to £1,740 p.a.

A contributory Pension Scheme is in operation.

Houses for renting by successful married candidates may be available in due course, or alternatively, substantial assistance may be given towards legal expenses incurred in private purchase.

Suitably qualified persons are invited to send postcard, quoting reference 2060, for application form to Recruitment Officer, U.K.A.E.A., Industrial Group Headquarters, Risley, Warrington, Lancashire.

CLOSING DATE : 21ST OCTOBER, 1957.

UNIVERSITY COLLEGE OF RHODESIA AND NYASALAND

Applications are invited for Lectureship in Physics. Salary scales : Assistant Lecturer £1,050 × 50–£1,200 p.a., Lecturer (Grade II) £1,200 × 50–£1,450 p.a., (Grade I) £1,450 × 50–£1,750 p.a., entry point determined by qualifications and experience. Superannuation scheme. Passages to Salisbury for appointee, wife and dependent children on appointment with allowance for transport of effects. Unfurnished accommodation at rent of up to 15 per cent of salary.

Detailed applications (six copies) naming three referees by October 31, 1957, to Secretary, Inter-University Council for Higher Education Overseas, 29 Woburn Square, London, W.C.1, from whom further particulars may be obtained.